TWO-IMPACT CRASHES—IMPLICATIONS FOR OCCUPANT PROTECTION TECHNOLOGIES

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ABSTRACT

The widespread and increasing use of deployable devices for improved occupant protection has created new opportunities to design vehicles for multiple impact accidents. It is therefore of topical interest to understand how often multiple impacts occur; which order and combination of impacts (front, side, rear) are most frequent; whether the first, second or subsequent impact is most severe; whether occupants are injured on the first, second or subsequent impacts. In-depth accident files from the UK Co-operative Crash Injury Study 1992-2001 were reviewed, focussing on restrained occupants with MAIS 3+ injury severity where the vehicle received (exactly) two impacts in the course of the accident. The accident data shows that the first impact is the most severe in about 75% of these cases and indicates that injuries are very highly associated with the more severe impact.

Keywords:

in-depth accident data, multiple impact, occupant protection, restraint systems, deployment, injury severity

INTRODUCTION

The widespread and increasing use of deployable devices for improved occupant protection has created new opportunities to design vehicles for multiple impact accidents. Current systems, such as air bags, typically deploy only once and operate effectively for a fraction of a second. If a vehicle incurs more than one impact during an accident and deployable systems are activated on the first impact, then they are not necessarily available for the second and subsequent impacts that may occur. It is therefore of topical interest to understand how often multiple impacts occur; which order and combination of impacts (front, side, rear) are most frequent; whether the first, second or subsequent impact is most severe; whether occupants are injured on the first, second or subsequent impacts.

RESULTS

The results presented in this paper are based on the in-depth UK Co-operative Crash Injury Study (CCIS) 1992-2001. The study collects detailed vehicle damage and occupant injury information from a sample of (occupant) injury accidents that occur in selected regions around England. Both the case vehicle, which must have been less than seven years old and towed away from the scene of the accident, and its collision partner are eligible for inclusion. The sample is weighted towards fatal and serious accidents.

Table 1.
Impact Type for MAIS 3+ Occupants (N=1274)

Impact type	driver	front pass.	rear pass.
Single			
front	405	118	26
struck side	166	12	6
non struck side	73	60	3
rear	4	1	2
sub-total	648	191	37
Multiple			
2 impacts	135	42	8
3+ impact	29	12	2
Rollover	117	46	7

The analysis in this paper is focussed on restrained occupants injured to MAIS 3+ severity. This includes severe fractures, lacerations and many internal injuries, generally resulting in admission to a hospital bed. Table 1 shows frequency of impact type by seat position for 1274 MAIS 3+ restrained occupants. It can be seen that multiple (two-dimensional) impacts occur more often than rollovers. The majority of the multiple impacts are two-impact vehicles, i.e. vehicles that are coded as receiving two separate impacts in the course of the accident.

All following results apply to restrained occupants with MAIS 3+ injury severity where the vehicle received (exactly) two impacts in the course of the accident.

The documentation of each case was individually reviewed (a) to check the accident circumstances, in particular the sequence of events; (b) to assess the level of injury attributable to each impact; and (c) to assess whether each impact was individually of CCIS sample severity, i.e. of tow-away severity and injury-causing potential.

The CCIS tow-away sample criterion means that single impacts are severe enough to disable the vehicle. Where a vehicle has multiple impacts, it is not necessary that all recorded impacts are individually severe enough to render the vehicle undrivable. The second and third impacts (i.e. the less severe impacts) can be very minor; despite this, they are coded up by the vehicle examiners in just the same way as single impacts.

Table 2.
Timing of Impacts

	vehicles	
sequential	124	95%
simultaneous	3	2%
unknown	4	3%
total	131	100%

Table 2 shows how many times the impacts were believed to follow sequentially one after the other or to be simultaneous. The vast majority are coded as sequential. The timing of only a small number of impacts was considered to be unknown. CCIS vehicle examiners rarely visit the scene of an accident. The judgment of impact timing is mostly based on the description of accident circumstances recorded in the police report.

Table 3.
Object Struck

	vehicles	
same object	34	26%
separate objects	92	70%
other/unknown	5	4%
total	131	100%

It is difficult to ascertain the duration between impacts without making an at-scene investigation. When the same object is struck twice, e.g. following rotation of the colliding vehicles, it is likely that the duration between impacts is relatively short. Table 3 shows that the same object is struck twice in 26% of cases. As the duration between impacts can also be short when separate objects are struck, this is a conservative estimate of the percentage of cases in which the impacts follow in quick succession.

Table 4.
Severity of Impacts (N=131)

	Impact severity		
	tow-away or injury	AIS 1+	AIS 2+
one impact only	46%	77%	89%
both impacts	54%	22%	11%
other/unknown	0%	1%	1%
total	100%	100%	100%

Table 4 provides three indications of the extent to which two-impact vehicles are adequately covered by the design of safety systems for single impacts.

The assessment of whether both or only one impact was of CCIS sample severity (tow-away or injury potential) is necessarily subjective. The judgement was made conservatively, i.e. if in doubt, impacts were categorised as having tow-away or injury potential. By this criterion almost half (46%) of two-impact vehicles could be considered as incurring only one significant impact

In reviewing the individual accident reports, it was usually fairly clear which injuries were attributed to the first or second impact, especially at the more severe levels. Table 4 shows the number of vehicles for which both impacts, jointly or independently, were considered to contribute to AIS 1+ injuries. Over three-quarters of vehicles had only one injury-causing impact, even at the level where bruises, abrasions and other AIS 1 injuries are taken into consideration

An even larger proportion of vehicles (89%) had only one impact that contributed to injury at the more severe AIS 2+ level. Vehicle safety systems would normally be designed for this level of injury, from which it can be concluded that design for multiple impacts is required for around one in ten cases of two-impact vehicles, based on the CCIS sample

Table 5.
Most Severe Impact (N=124)

	Impact		
	first	second	total
Front	43 83%	9 17%	52 100%
Side	45 76%	14 24%	59 100%
Rear	7 54%	6 46%	13 100%
total	95 77%	29 23%	124 100%

Table 5 describes when the most severe impact occurred. When front and side impacts are the most severe impact, they occur predominantly as the first impact (83% and 76% respectively). This suggests that the design of safety systems for single impacts mostly covers double impacts too. Nonetheless there remains a significant minority of cases (17% and 24% for front and side impacts respectively) in which it could be appropriate for deployable systems to be operational on the second impact. When rear impacts are the most severe impact, they are roughly equally balanced between occurring first or second.

Table 6.
Sequence of Impacts: All Impacts

First impact	Second impact front	side	back	total
front	4	43	10	57
side	17	43	6	66
back	6	1	1	8
total	27	87	17	131

Table 7.
Sequence of Impacts: Both at AIS 1+ Level

First impact	Second impact front	side	back	total
front	3	8	3	14
side	5	7	0	12
back	3	0	0	3
total	11	15	3	29

Table 8.
Sequence of Impacts: Both at AIS 2+ Level

First impact	Second impact front	side	back	total
front	1	5	1	7
side	2	3	0	5
back	2	0	0	2
total	5	8	1	14

Table 6, Table 7, and Table 8 show the sequence of impacts for all impacts and for cases where both impacts were considered to be relevant at the AIS 1+ and AIS 2+ levels.

The trend in these tables is that front impacts followed by side impacts, and side impacts followed by a second side impact, are the most frequent events and constitute around half of all double impacts. In the context of deployable safety systems this (a) highlights the importance of activating front, left and right systems independently and (b) points to the possibility of maintaining the deployed state of side systems for an extended duration of time in order to cover the occasions when the same side is struck twice.

Table 9.
Maximum Injury Severity for Sequential Impacts (N=129)

Impact	Injury severity nil	AIS 1	AIS 2	AIS3+	total
first	19%	5%	1%	75%	100%
second	60%	5%	1%	33%	100%

Table 9 shows the maximum level of injury associated with the first and second impacts. Earlier it was shown that the first impact is the most severe impact about three-quarters of the time (see Table 5). This is reflected in Table 9, where the first impact was involved in an AIS 3+ injury for 75% of occupants. The second impact was considered to be involved at the AIS 3+ level, either independently or jointly, in 33% of cases. It is worth mentioning again that these occupants are a MAIS 3+ sample and therefore by definition have at least one AIS 3+ injury.

A detailed breakdown of the impact type of the first and second impacts that contributed to AIS 3+ injury is shown in Table 10 and Table 11. These results can be compared to the distribution of impact type for single impacts described above (cf. Table 1).

Table 10.
Impact Type for AIS 3+ Injuries on First Impact (N=103 occupants)

		driver	FSP	rear
Frontal	narrow			
	underrun	7		1
	offset	13	2	
	intermed.	6	2	
	full	12	6	
Struck side	underrun	7	1	2
	narrow	2	2	
	wide	12	6	
Non-struck side	underrun	3		
	narrow			
	wide	6	4	1
	other	1		
Rear	narrow	4	3	

Table 11.
Impact Type for AIS 3+ injuries on Second Impact (N=46 occupants)

		driver	FSP	rear
Frontal	narrow		2	1
	underrun	2	1	
	offset	2		
	intermed.	5		
	full	3	1	
Struck side	underrun	2		
	narrow	2	1	1
	wide	10	1	2
Non-struck side	underrun			
	narrow	2		
	wide	2		
Rear	narrow			
	underrun	2		
	offset			
	intermed.			
	full	2	2	

These results confirm from injuries what was already seen from impact severity: that the first impact is the first priority for the design of safety systems and that the proportion of significant events on the second impact is high enough to warrant attention.

Table 12.
Maximum Injury Severity for More and Less Severe Impacts (N=124 occupants)

	Injury severity associated with impact				
	nil	AIS 1	AIS 2	AIS3+	total
more severe	1%	2%	0%	98%	100%
less severe	80%	8%	2%	10%	100%

Table 12 shows how injuries are associated with the more and less severe impact. As expected, among this sample of MAIS 3+ occupants, the more severe impact is involved in an AIS 3+ injury in virtually all cases (98%). The less severe impact is involved in serious injury in one in ten cases. This indicates that a priority for deployable systems is to be activated on the more severe impact. This will automatically result in appropriate protection for the majority of double impacts even if the systems are designed for single impacts.In practice, single-activation systems are available on the second impact if minor first impacts due not exceed the deployment threshold.

CONCLUSION

Among the two-impact MAIS 3+ CCIS sample of cases reviewed, the less severe impact is relevant to serious injury in around 10-12% of cases. The more severe impact occurs as the first impact for over 75% of double impacts.

The accident data reviewed indicates that vehicle safety systems designed for single impacts are probably already substantially effective for double impacts. A priority for deployable systems is to activate at a threshold that retains their protective effect in the event of a second, severe impact. It is also appropriate that front, left, right, and rear deployable systems activate independently as required. Increasing the duration of time over which deployable side protection systems maintain their activated state could further extend the protection of occupants against double impacts on the same side.

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Further information on CCIS can be found at http://www.ukccis.org